VARIATIONS IN THE NUMBER AND ATTACHMENT OF PAPILLARY MUSCLES

Dissertation Submitted to

THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY

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In partial fulfillment of the regulations
for the award of the degree of

M.S. (Anatomy)

BRANCH – V

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CERTIFICATE

This is to certify that the dissertation titled **"Variations in the number and attachment of papillary muscles"** is a bonafide work done by **Dr. N.S. Radhakrishnan**. It is a regular systematic study done under my guidance and submitted for ensuing M.S (Anatomy)., Branch V examination on March 2009 of the Tamilnadu **Dr. M.G.R. Medical University**, Chennai.

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DECLARATION

I solemnly declare that the dissertation titled **"Variations in the number and attachment of papillary muscles"** was done by me in the Department of Anatomy, Govt. Stanley Medical College & hospital, Chennai -600001, under the guidance and supervision of **Dr S.Chitra M.S** (Anatomy), Professor and Head of the department, Department of Anatomy, Govt. Stanley Medical College, Chennai–1. This dissertation is submitted to the Tamilnadu Dr M.G.R. Medical University towards partial fulfillment of the requirement for the award of M.S degree (Branch V) in Anatomy.

Place :

Date :

Dr. N.S.Radhakrishnan.

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CONTENTS

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INTRODUCTION

Many years have elapsed since the human body was attempted to be described. Though the human body remains the same, the understanding of it has changed immensely and continues to do so. Research works carried out in various parts of the world contribute newer information everyday. As the other fields of science, the field of Anatomy is also changing day by day. With advances in imaging techniques, understanding of body structures has changed to a great extent. The present study is a step towards adding some more information to existing data on the possible variations in the Anatomy of cardiac papillary muscles.

Papillary muscles are part of the valvular complex, and are very important in proper functioning of the valve mechanism of the human heart. They are small projections seen in the lumina of both ventricles; they hold the valve cusps from prolapsing back into the atria during systole thereby preventing regurgitation.

Several variations have been reported in their anatomy and arrangement. They vary in number and in their attachments, both basal and apical.

They were first studied by Rusted and co- workers in 1952 ; since then several studies have been conducted to present competent data about the possible variations of these muscular projections.

The present study is done with the purpose of providing relevant information about variations in the number of papillary muscles in each ventricle in South Indian population.

The area of attachment of the base of these muscles and the chordal attachment have also been studied. Emerging observations and attendant data have been compiled systematically throwing insight into the valvar complex.

AIM OF THE STUDY

Papillary muscles are part of myocardium; and are very important in the proper functioning of the atrioventricular alves. Variations in the anatomy of the papillary muscles can result in several clinical problems.

One such condition where the variation in the number sequels into mitral stenosis is the “Parachute Valve syndrome”. In this condition, instead of the two usual papillary muscles in the left ventricle, there exists a single large muscle with multiple chordae tendinae that arise from it and run to both cusps.

In congenital elongation of papillary muscles and chordae tendinae, the end result is a mitral regurgitation due to defective valve closure.

Another important condition is the ‘ Anomalous papillary muscle arcade” where a fibrous cord is seen stretching between the two existing papillary muscles and the result may either be a stenosis or regurgitation.

Papillary fibroelastoma is one of the benign cardiac tumors, where the histologic appearance resembles normal chordae tendinae and may result in embolic events if not identified early.

There exists a possibility of arrhythmias arising from one of the papillary muscles, and in such patients surgical correction would be needed if the arrhythmia is intractable Adequate knowledge about the position and structure of papillary muscles is therefore absolutely essential.

Partial or complete rupture of the papillary muscles are well known complications of myocardial infarction. It assumes greater importance as there is a possibility of fatality if not diagnosed and treated promptly.

The choice of an appropriate surgical procedure presupposes adequate and quantitative knowledge of the papillary muscles.

The present study is aimed at

1. Examining the pattern of variations in the number and attachment (basal & apical) of papillary muscles in South Indian population.

2. Comparing the results with previously existing data.

3. Analyzing the pattern to provide categorical outlay of management and providing additional information to the clinicians which help them in deciding the management.

ANATOMICAL CONSIDERATIONS

Structure of the heart

The heart consists mainly of muscles called the myocardium, which is enclosed between the epicardium or visceral layer of pericardium and the endocardium.

Epicardium consists of white fibrous and elastic tissue which is covered with flat polygonal mesothelial cells on its free surface.

Endocardium is much thinner than the epicardium and it consists of lining of endothelial cells, a layer of fine areolar tissue and an external elastic layer in the form of fenestrated membrane.

The cardiac muscle fibres (myocardium) have the characteristic and definite arrangement in different parts of the heart.

In the atria the muscle fasciculi fall into two groups;

(i) superficial group common to both atria and

(ii) deep fibres peculiar to each atrium.

In the ventricles the muscular fasciculi form less definite v shaped loops which begin and end at the fibrous rings at the bases of the ventricles. These loops embrace the cavities of either one or both ventricles, one limb of each loop lying

on the outer surface of the heart and the other in the interior. The superficial fibers on the sterno costal surface pass towards the left, those on the inferior surface towards the right. At the apex all are coiled into a whorl or vertex through which they pass into the interior of the ventricular walls and run towards the base, some in the septum and others end in the papillary muscles.

Interior of the right ventricle

The cavity of the right ventricle is c shaped in cross section, the posterior limb receives the blood from the right atrium and appeared rough with prominent muscular ridges. the anterior limb of c is the outflow part of the right ventricle which appeared smooth and called conus arteriosus.

The muscular ridges in the inflow part are called trabaculae corneae. These trabaculae corneae divided into three types, first type is just a ridge, second type having attachment of both ends to the ventricular wall but raised middle part, third type having base attached and apex projecting into the lumen.

The third type is called papillary muscles. There are usually three sets of papillary muscles in the right ventricle, namely anterior, posterior and septal. They are named according to the location of their bases. From the apex of each papillary muscle several tendon like fibrous cords, known as chordae tendinae extend to the cusps of the atrioventricular valves.

Among these papillary muscles the largest and most constant one is anterior papillary muscle, the septal muscle is tiny and may be even absent with chordae tendinae arising directly from the ventricular wall. The posterior papillary muscle is smaller than the anterior and has one to three bellies.

Interior of the left ventricle

The myocardium of the left ventricle is thicker than that of right ventricle . the cavity is conical, and In cross section appears more or less circular. Inflow and outflow parts are not as clearly demarcated in the left ventricle as in the right ventricle.

The trabaculae corneae in the left ventricle are fine and delicate in contrast to the coarse trabaculae corneae in the right ventricle. There are usually two papillary muscles in the left ventricle, an anterior and posterior; to be more precise anterolateral and posteromedial according to their attachment.

Either of two papillary muscle may show duplication. The choradae tendinae of each of these muscle run to the commisural area and has an attachment to both cusps of mitral valve.

REVIEW OF LITERATURE

Rusted IE, Schiefley CH, and co-workers were the earliest to study mitral valve anatomy. After a study of 200 human hearts, they presented a detailed anatomical report in 1952.

By their study, the left ventricle usually has two large papillary muscles that send chordae tendinae to both cusps of the mitral valve. Among these two, the anterior is situated in the anterolateral wall and often, is single. This particular muscle and its chordae are guides to the anterolateral commissure. The muscle was found to be single in 76.5%, though it was frequently found to be grooved lengthwise. The muscle was double in 12%, and triple in 9.5%.The posterior papillary muscle is attached to the posteromedial wall. It is smaller in size than the anterior muscle. It was single in 30%, double in 26.5%, triple in 37% and more than three in 6%.

In 1995, a similar study conducted by Solomon Victor and VM Nayak in 100 human hearts showed a slightly different result pattern in South Indian population. According to this study conducted in Madras Heart Institute, the anterior papillary muscle of the left ventricle is single in 67%, double in 27%, triple in 4%, quadruple in 1% and penta in 1%. The posterior papillary muscle was found to be single in 50%, double in 36% triple in 11% and quadruple in 3%. Attachment of these muscles to the ventricular wall and their chordae have

also been studied and the data presented. The anterior papillary muscle is attached to the upper third in 19%, middle third in 79.5% and to the lower third in 1.5%. The corresponding figures for the posterior muscle are 6%, 92.5% and 1.5% respectively. 4 to 20 chordae tendinae have been found to arise from each papillary muscle and they end in 14 to 72 chordal insertions. Likewise 2 to 18 chordae tendinae were found to arise from each of the posterior papillary muscle and they ended in 12 to 80 insertions.

G.R.Negri, L.J.A.Di Dio et al studied seventy nine human hearts and reported on the morphological characters of the papillary muscles of the right ventricle and their chordae tendinae. According to their study the anterior and posterior papillary muscles are present in 100%; the septal muscle absent in 21.5%; anterior papillary muscle single in 81% and double in 19%; septal papillary muscle single in 41.7% , double in 16.5% triple in 12.7% and quadruple in 7.6%; likewise posterior papillary muscle single in 25.4%, double in 46.8%, triple in 21.5% and quadruple in 6.3%. The chordae tendinae of the anterior papillary muscle ranged from 1 to 11 (mean 4.74), of the posterior papillary muscle ranged from 1 to 8 (mean 2.62) of the septal papillary muscle ranged from 1 to 5 (mean 1.77).

Acar and collegues (1996) have proposed a clinical morphologic classification of the papillary muscles. They are of four types; type I is single and Undivided; type II cleaved in sagittal plane; type III cleaved in coronal plane with an

individual head that supports the commissural chordae; type IV refers to the papillary muscle that is divided into multiple heads.

Atkin O, Kocak Aytec and collegues have done extensive work on the tricuspid valve complex. According to their study in 400 human hearts there were minimum of two and maximum of nine papillary muscles in the right ventricle and they were named into anterior, posterior and septal papillary muscles. The cardiac deaths were more frequent in patients who had one headed anterior papillary muscle as per their inference.

Anderson RH, Becker AE in 1980 have reported anatomical variations of the papillary muscle, as per their study the anterior papillary muscle of the left ventricle in largest of the papillary muscle.

Austen, in 1965 was the first one to perform mitral valve replacement for papillary muscle rupture and he reported several variations of papillary muscle in his clinical studies.

Carpentier and Duran, in 1965 performed reconstruction of ruptured papillary muscles and reported about the newer techniques in performing post infarction papillary muscle rupture surgeries.

Estates EH, Dalton FM et al , in their study of “The Anatomy and Blood supply of the papillary muscle of the left ventricle”, have reported that anterior papillary muscle has got

dual blood supply from anterior descending artery and circumflex artery and posterior papillary muscle had single blood supply either from left circumflex or from distal branch of right coronary artery.

Lam JH, Ranganathan et al have presented a classification of the chordae tendinae in their morphological study of mitral valve, according to them chordae tendinae can be classified into cleft, commissural and basal chordae based on their attachment to the valve cusp.

Merrick AF, Yacoub MH, Anderson RH have published a study on the "Anatomy of subpulmonary infundibulum with regard to Ross procedure".

Mc Goon was the first one to perform repair of ruptured chordae tendinae in 1960 and he had presented clinically relevant details of the papillary muscles.

Roberts and Cohn , in 1977 have detailed papillary-chordal Anatomy and pathologic states in ischemic conditions. They have reported that there were 9 chordae tendinae, arose on an average from anterior papillary muscle and 14 chordae tendinae arose on an average from the posterior papillary muscle of the left ventricle.

Sanchez- Quintana D, Garcia –Martinez V, Hurle JM have studied the morphological changes in normal pattern of ventricular myocardium.

Tandler J studied the valve complex and defined three orders of chordae tendinae; those which were attached to free edge of the valve cusp, those which were attached few mm away from the free edge and those attached to the base of the cusp as three different categories of chordae tendinae.

According to the Gray's text book of Anatomy, valve complex consists of atrioventricular orifice and its annulus, valvular leaflets or cusps, chordae tendinae and papillary muscles.

In the left ventricle ,usually there are two papillary muscles which may vary in length, breadth and may be bifid. Chordae tendinae mostly arise from the tip or apical third of each muscle, but sometimes near the base. They diverge and are inserted to the corresponding commisure.

The right ventricular papillary muscles are two primarily, the anterior and the posterior with variable small septal papillary muscle. The anterior papillary muscle is the largest; the posterior muscles are often bifid or trifid; septal papillary muscles may be absent or merely irregular fibrous chords. More often a group of small papillary projections arise from the infundibular septal wall , the highest is termed papillary muscle of the conus.

According to cunningham's text book of Anatomy, the interior of the ventricles have muscular ridges called trabaculae corneae the prominent projecting ones are called papillary muscles.

In the left ventricle there are two papillary muscles, the anterior arising from the sternocostal wall and the posterior arising from the inferior wall. Each is connected by chordae tendinae to the cusps of the mitral valve.

The papillary muscles of the right ventricle are

(i) large anterior papillary muscle from which chordae tendinae pass to the anterior and posterior cusps.

(ii) posterior papillary muscle , more often represented by two or more bellies from which the chordae tendinae pass to the posterior and septal cusps and

(iii) a variable group of small septal papillary muscles whose chordae pass to the septal and anterior cusps.

As per the Hollinshed text book of Anatomy, there are several variations in the anatomical arrangement of papillary muscles.

In the left ventricle there are usually only two papillary muscles , namely anterior and posterior ; the anterior papillary muscle is arising from the anterolateral wall and the posterior papillary muscle arsing from the posteromedial wall. Anterior papillary muscle is the largest, more often single, although it may be grooved lengthwise and gives chordal attachment to both cusps of the mitral valve. The posterior is smaller than the anterior, more often has multiple bellis and it gives chordal attachment to both cusps of the mitarl valve.

In the right ventricle there are three groups of papillary muscles, namely anterior, posterior and septal; the anterior is usually single , largest of the three and most constant one, the septal papillary muscle is tiny and may be absent, there may be one to three posterior papillary muscles.

In the text book of cardiac surgery by Kerklin the anatomical variations of the papillary muscle is described as Followed;

The mitral valve complex has two papillary muscles, the anterior and the posterior . There were patterns of mostly single or two muscle bellies , but occasionally three, four or even five bellies were observed. When there are three bellies the papillary muscle supporting the chordae tendinae to the commisure arises separately from the ventricular wall.

Commisural chordae tendinae are shorter alnd usually originate from the highest tip of the papillary muscle.

The tricuspid valve complex has two principal papillary muscles, the anterior and posterior and small variable septal papillary muscle. The chordae tendinae to the anterior leaflet arising from the anterior and septal papillary muscle, chordae to the posterior leaflet from the posterior and anterior papillary muscles and chorade to the septal leaflet arising from the septal and posterior papillary muscles..

MATERIALS & METHODS

A total number of 100 hearts have been evaluated from various sources

- ✓ Twenty three specimens were collected from the cadavers used for undergraduate training in the department of Anatomy, Stanley medical college.

- ✓ Thirty cadaveric specimens observed during the post mortem in the Forensic Medicine department, Stanley medical college.

- ✓ Two neonates which were preserved in the department of Anatomy were dissected and the specimen retrieved.

- ✓ Magnetic resonance images of twenty hearts were studied in the Radiology department, Stanley Medical College.

- ✓ Twenty hearts imaged through the transesophageal echocardiography in the Cardiology department of Stanley Medical College.

1. Dissection in the Anatomy department

The heart specimens retrieved from the cadavers in the dissection hall, Anatomy department during undergraduate training. the specimen thus obtained were thoroughly cleaned, then incision made through the lateral wall. Again the specimen were washed to remove the remaining clots and the interior of the ventricle studied.

2. Specimens from the Forensic department

During the postmortem in the forensic department the specimens were retrieved and thoroughly washed in the running water. Then the dissection procedure done there itself similar to the dissection in the dissection hall. After removing all the clots the interior of both ventricles exposed and the study undertaken.

3. Neonatal specimen dissection

Two neonates were received in our department from the neonatal unit. They were embalmed by routine method. Then they were taken for dissection. Sternum was cut by midline incision. The incision made meticulously to avoid injury to the heart, then heart removed by incising and removing the pericardium carefully. The great vessels of the heart cut as closely as possible to the heart and then specimen retrieved. The specimen washed well and the dissection of the heart carried out as described in the adult specimen dissection.

4. Transesophageal echocardiogarhy

After obtaining necessary permission from the ethical committee and the head of the department this study was done in the department of cardiology.

The patients were asked to come on empty stomach after overnight fasting. Consent from the patient obtained in approved format . then the patient was placed in left lateral postion. ECG monitor connected, then after placing the gag the probe introduced through oral route as in upper GI endoscopic procedure. Then imaging done in two dimensional B mode ultrasonography using the Aloka SSD 4000Sv colour dopller ultrasonographic machine.

5.Magnetic resonance imaging.

After obtaining necessary permission from the ethical committee and the concerned authorities the images in the Radiology department of Stanley Medical college were reviewed. The study was conducted using the Siemens 2T MRI machine. The necessary approved consent form was given to the patients who were undergoing body MRI imaging for other than cardiac complaints. Under ECG gating and spinecho pulse sequence, images were obtained in sagittal, coronal , axial planes and in oblique planes by both dark blood and white blood techniques. The images thus obtained are studied to assess the papillary muscle.

OBSERVATION

The present study is conducted in 100 human hearts (Sixty cadaveric specimens, twenty from transesophageal echocardiography and twenty from magnetic resonance imaging).

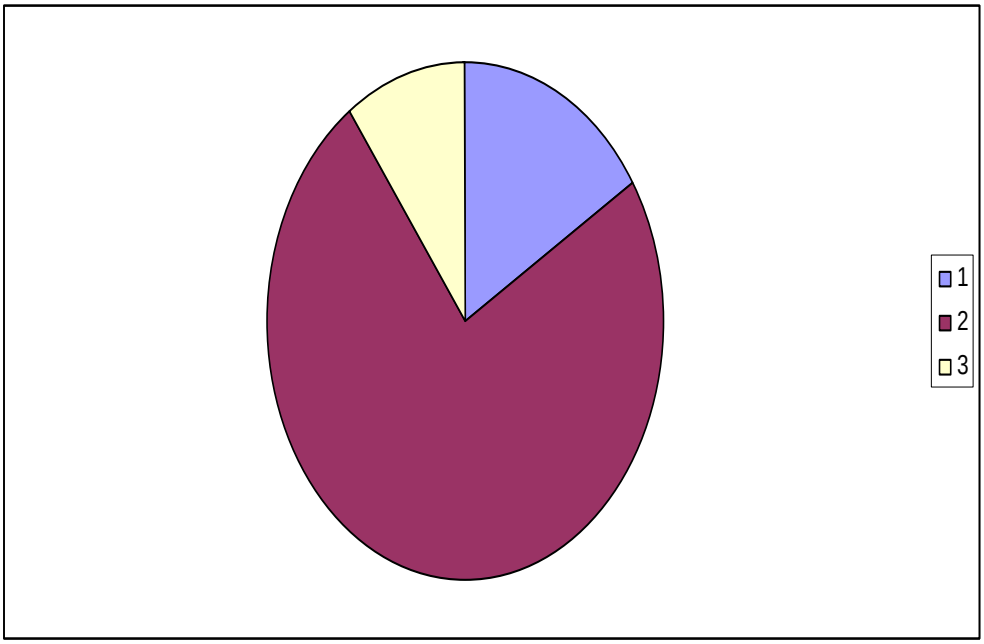
Several variations could be observed in the number of papillary muscles, their basal attachment and the number of chordae tendinae arising from each papillary muscle, and the results are compiled here in systematic manner.

In the left ventricle the anterior papillary muscle had their bases attached to the upper third in sixteen (16 %) out of hundred specimens , to the middle third in seventy four (74%) out of hundred specimens, and to the lower third in ten (10%) out of hundred specimens.

The corresponding figures for the posterior papillary muscle in the hundred specimens studied were Thirteen (13%), eighty one (81%) and six (6%)

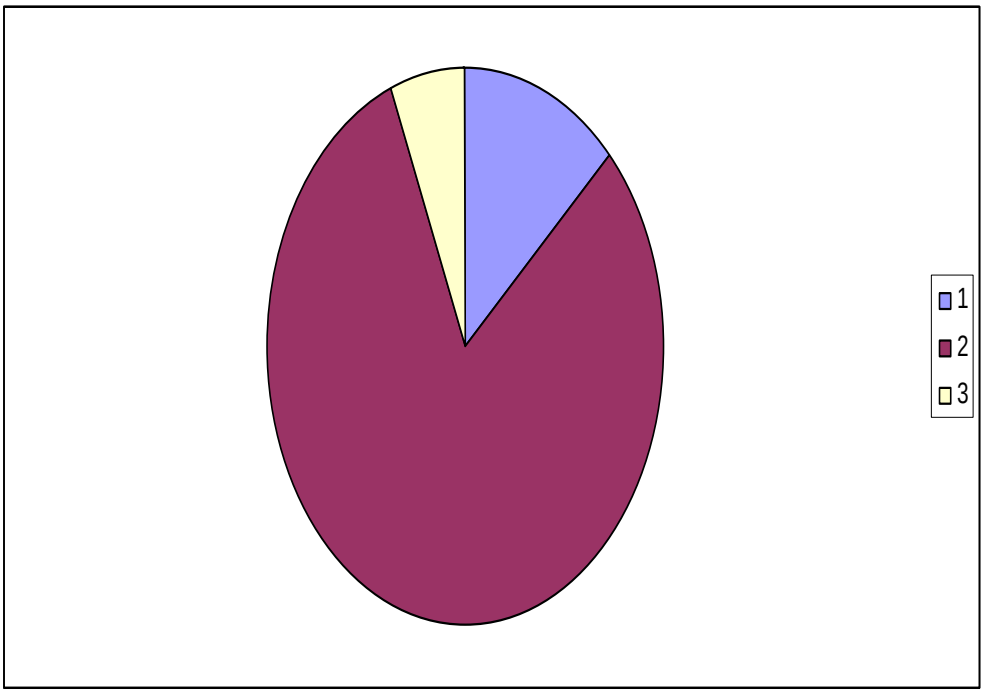
Anterior papillary muscle of the left ventricle

1	Upper third	16%
2	Middle third	74%
3	Lower third	10%



Posterior papillary muscle

1	Upper third	13%
2	Middle third	81%
3	Lower third	6%



In the right ventricle the attachment of the bases of the various groups of papillary muscles were observed.

The anterior papillary muscle was attached to

The upper third in seven(7%)

The middle third in eighty six (86%) and

The lower third in seven (7%) percent of the specimens.

The posterior papillary muscle was attached to

The upper third in nine(9%)

The middle third in eighty eight (88%)

The lower third in three (3%) percent of the specimens.

The septal papillary muscle was attached to

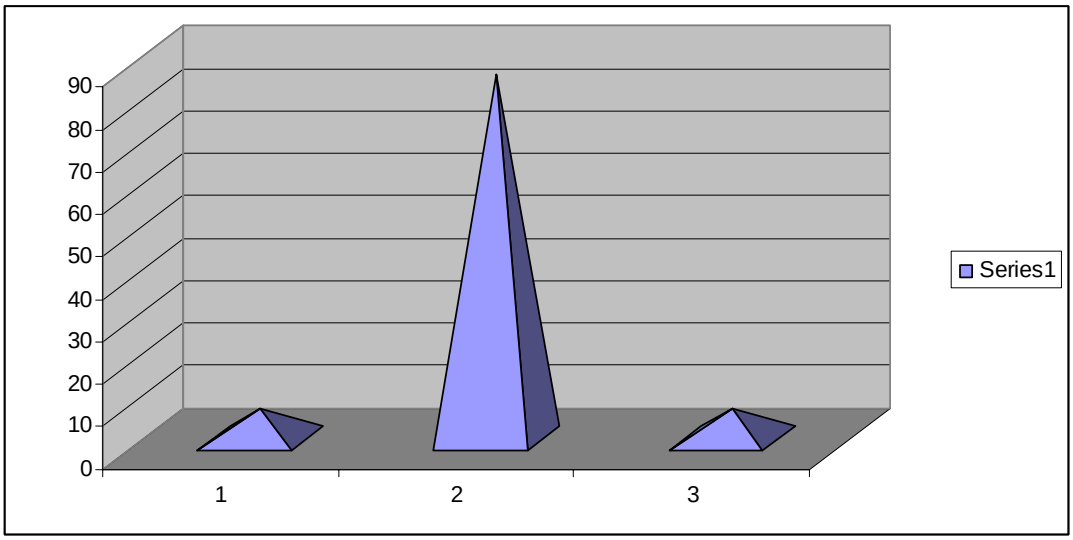
The upper third fifty eight (58%)

The middle third twenty four (24%)

The lower third eighteen (18%) percent of the specimen.

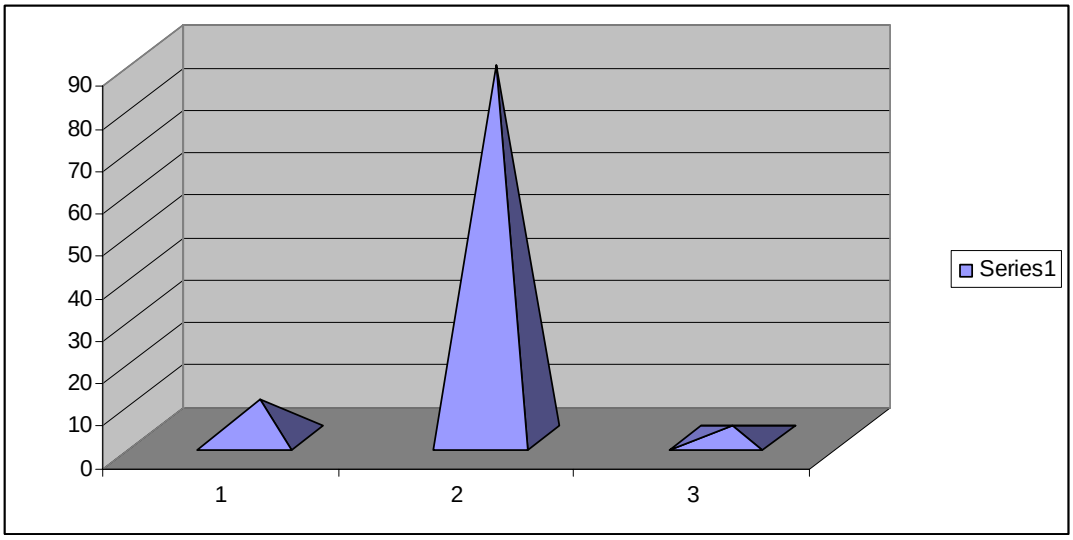
Anterior papillary muscle of the right ventricle

1	Upper third	07%
2	Middle third	86%
3	Lower third	07%



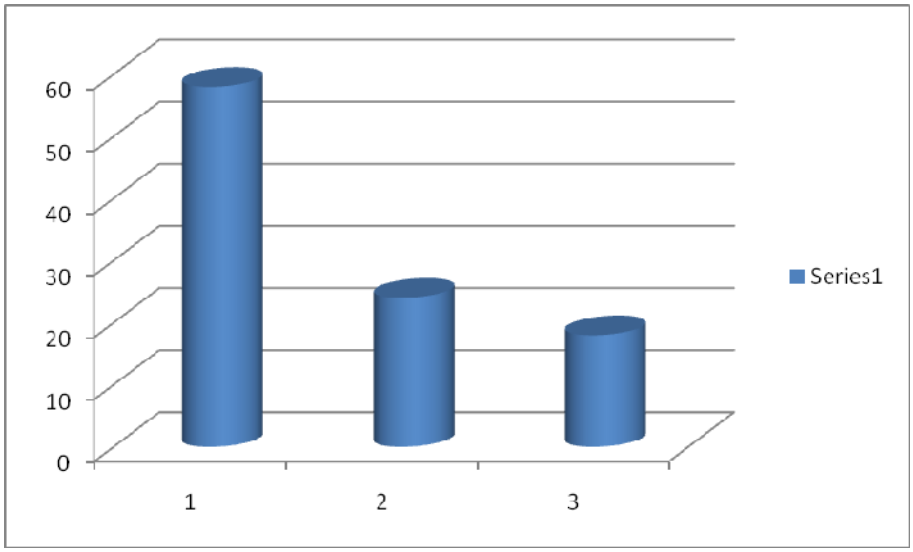
Posterior papillary muscle of the right ventricle

1	Upper third	09%
2	Middle third	88%
3	Lower third	03%



Septal papillary muscle of the right ventricle

1	**Upper third**	**58%**
2	**Middle third**	**24%**
3	**Lower third**	**18%**

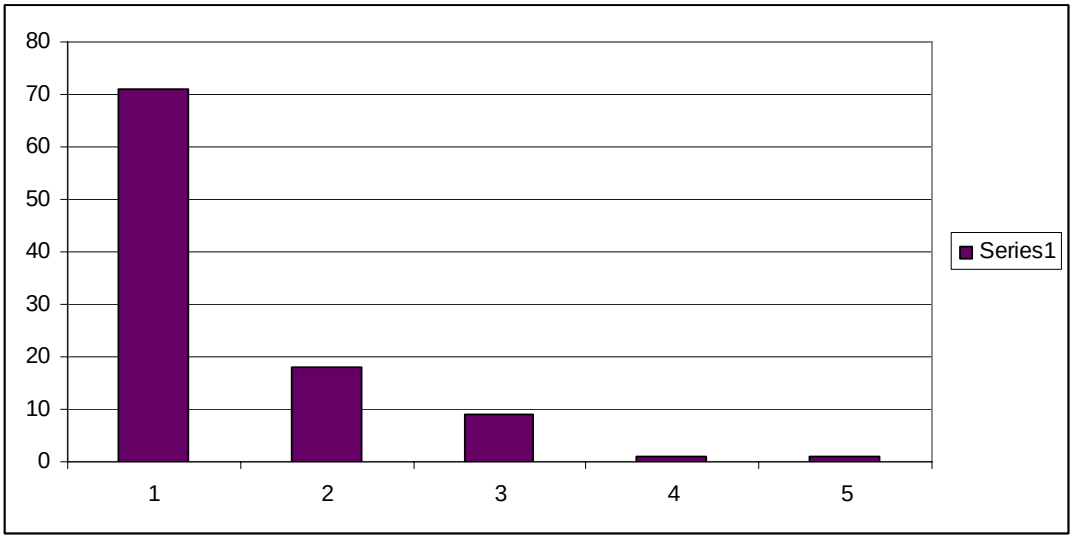


The variations In the number and the configuration of papillary muscles were also studied.

In the left ventricle the anterior papillary muscle had
Single belly in seventy one (71%),
two bellies in eighteen (18%)
three bellies in nine (9%) ,
four bellies in one (1%) and
five bellies in one (1%) percent of the specimen.

Anterior papillary muscle of the left ventricle.

1	**one belly**	**71%**
2	**Two bellies**	**18%**
3	**Three bellies**	**9%**
4	**Four bellies**	**1%**
5	**Five bellies**	**1%**



The posterior papillary muscle had

Single belly in forty eight (48%)

Two bellies in thirty nione (39%)

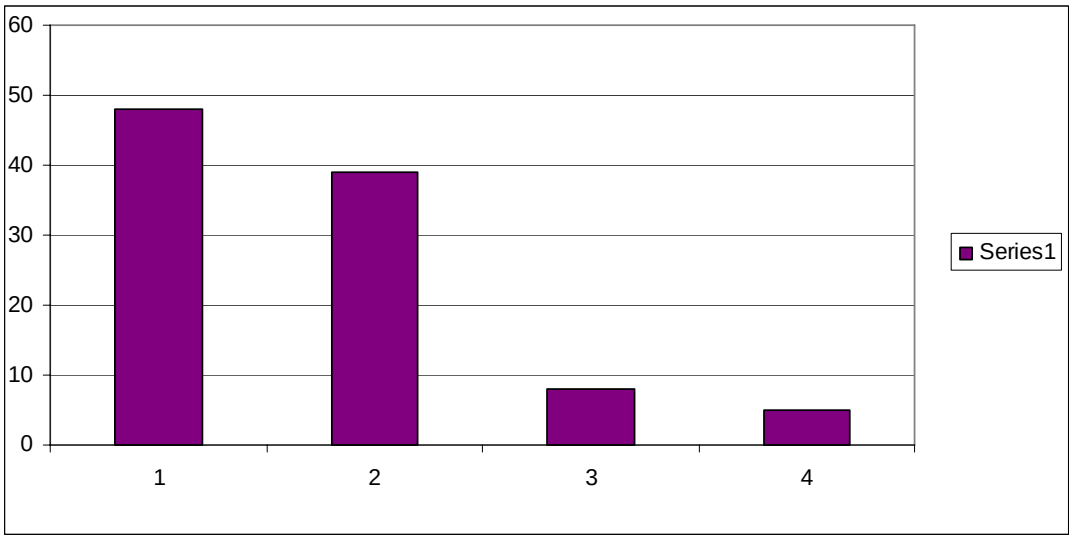
Three bellies in eight (8%)

Four bellies in four (4%)and

Five bellies in one (1%)

Posterior Papillary muscle

1	**Single belly**	**48%**
2	**Two bellies**	**39%**
3	**Three bellies**	**08%**
4	**More than three**	**05%**



In the right ventricle similar observation on variation in the number of the papillary muscles made.

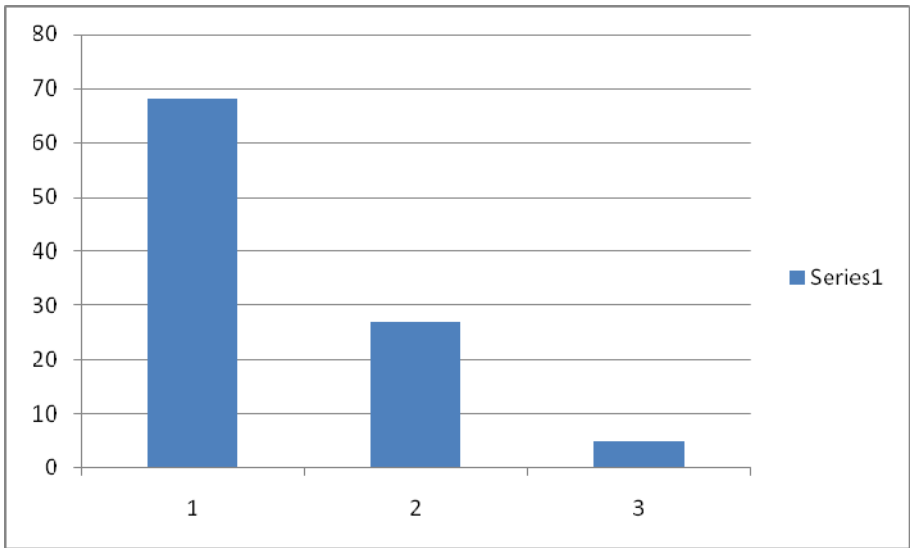
The anterior papillary muscle of the right ventricle was observed to have single belly in sixty eight (68%)

Two bellies in twenty seven (27%) and

Three bellies in the remaining fifteen (15%) percent of the specimens

Anterior papillary muscle of the right ventricle.

1	**Single belly**	**68%**
2	**Double bellies**	**27%**
3	**Three bellies**	**5%**



The posterior papillary muscle of the right ventricle was observed to have

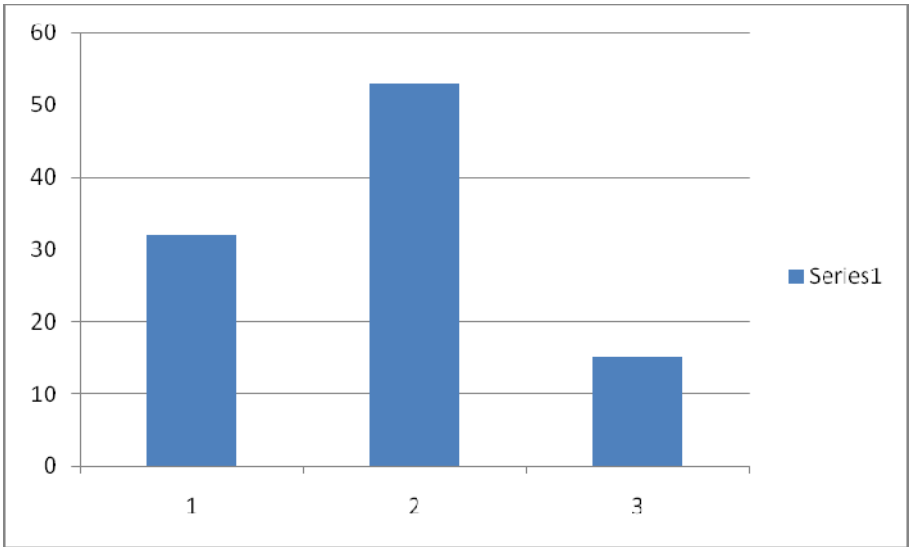
Single belly in thirty two (32%)

Two bellies in fifty three (53%)

Three bellies in the remaining fifteen (15%) percent of the specimens

Posterior papillary muscle of right ventricle

1	**Single belly**	**32%**
2	**Double bellies**	**53%**
3	**Three bellies**	**15%**



The septal papillary muscle was absent in forty nine (49%) of the hundred specimens observed and in all of them, chordae tendinae, varying from two, three, four or five seen arising directly from the ventricular wall. The corresponding figures for each group is

eight out of forty nine (two chordae tendinae)

thirty two out of forty nine (three chordae tendinae)

six out of forty nine (four chordae tendinae) and

three out of forty nine (five chordae tendinae)

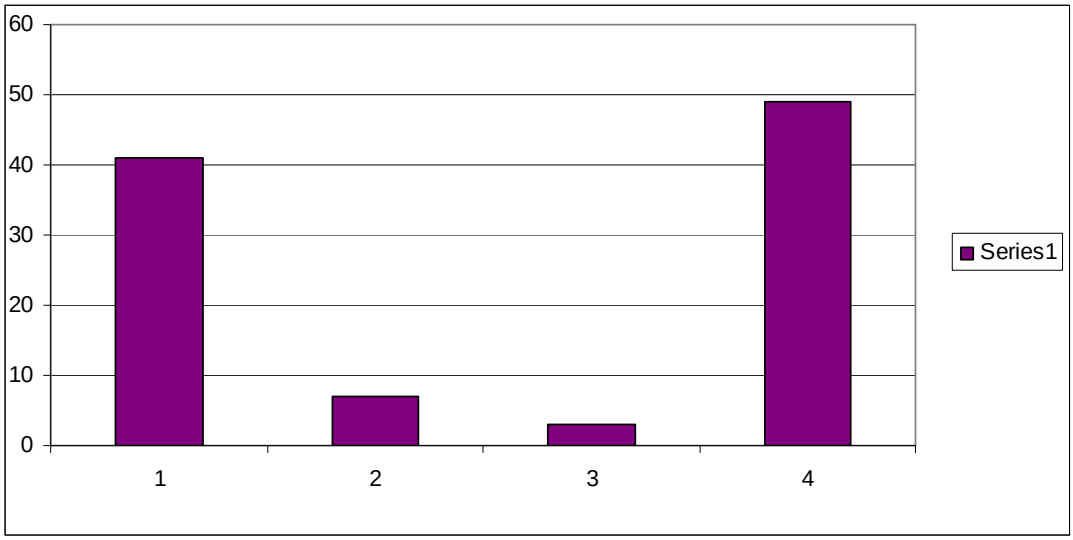
Those which had single small and nipple like papillary muscle showed one, two or more group of chordae tendinae arising directly from the ventricular wall. This group comprised forty one(41%) percent of the specimen observed.

In seven hearts (7%) there were two papillary muscles and they had some extra chordae tendinae arising directly from the wall.

Three (3%) percent was seen to have three papillary muscle with extra chordae tendinae arising directly from the wall of the ventricle.

Septal papillary muscle of right ventricle

1	Single belly	41%
2	Double bellies	7%
3	Three bellies	3%
3a	Four bellies	----
4	Absent	49%



On observing the chordae tendinae attached to each of the papillary muscle the following results were obtained.

The anterior papillary muscle of the left ventricle had minimum of three (3) chordae tendinae, maximum of fourteen (14) chordae tendinae and the average of eight (8).

The posterior papillary muscle had an attachment to minmum of two (2) chordae tendinae, maximum of fifteen (15) chordae tendinae and average of six (6) chordae tendinae.

For The anterior papillary muscle of the right ventricle the corresponding figures were one (1), six (6) and four (4).

For The posterior papillary muscle of the right ventricle the corresponding figures were one (1), fourteen (14) and two (2)

For the septal papillary muscle the corresponding figures were one (1) six (6) and three (3)

Anterior papillary muscle of the left Ventricle

Minimum number of chordae tendinae	**2**
Maximum number of chordae tendinae	**14**
Mean value	**8**

Posterior papillary muscle of the left Ventricle

Minimum number of chordae tendinae	**2**
Maximum number of chordae tendinae	**15**
Mean value	**6**

Anterior papillary muscle of the right Ventricle

Minimum number of chordae tendinae	**1**
Maximum number of chordae tendinae	**6**
Mean value	**4**

Posterior papillary muscle of the right Ventricle

Minimum number of chordae tendinae	**1**
Maximum number of chordae tendinae	**14**
Mean value	**2**

Septal papillary muscle of the right ventricle

Minimum number of chordae tendinae	**1**
Maximum number of chordae tendinae	**6**
Mean value	**3**

DISCUSSION

The results of the present study compared with the results of the previous study.

The first study of Rusted and co-workers have given a detailed anatomical picture of mitral valve complex. In our present study Anterior papillary muscle of the left ventricle found to be single in (71%) percent, compared to the Rusted's study result of 76.5% , two in 18% compared to 12% in the previous study, three in 9% compared to 9.5% of previous study , more than three 3 in 2% compared to 4% of the previous study.

The posterior papillary muscle of the left ventricle is single in 48% in the present study compared to 30% in the previous study, two in 39% , compared to 26.5% in the previous study, three in 8% compared to 37% in the previous study and more than three in 5% compared to the 6% in the previous study.

Anterior papillary muscle of the left ventricle.

	Present study	**Previous study**
Single belly	71	76.5
Two bellies	18	12
Three bellies	9	9.5
More than three	2	4

Posterior Papillary muscle

	Present study	**Previous study**
Single belly	48	30
Two bellies	39	26.5
Three bellies	8	37
More than three	5	6

While comparing the present study data in south Indian population with that of a previous study in western population the predominant group in western population is found to be three bellied posterior papillary muscle [37%] while it is single bellied in south Indian population [48%] .

The study by Solomon Victor and VM Nayak in 1995 is compared with the present study.

As per the present study the anterior papillary muscle of the left ventricle , had its base attached

to the upper third in 16%,

to the middle third in 74% and

to the lower third in the remaining 10%

The corresponding data of the previous study showed the attachment

to the upper third in 19%%,

to the middle third in 79.5% and

to the lower third in remaining 1.5%.

	Present study	**Previous study**
Upper third	16%	19%
Middle third	74%	79.5%
Lower third	10%	1.5%

Except for the attachment to the lower third all other data coincides with the previous study.

As per the present study the posterior papillary muscle Of the left ventricle , had its base attached.

to the upper third in 13%,

to the middle third in 81% and

to the lower third in the remaining 6% .

The corresponding data of the previous study were

to the upper third in 6%,

to the middle third in 92.5% and

to the lower third in remaining 1.5%

	Present study	**Previous study**
Upper third	13%	6%
Middle third	81%	92.5%
Lower third	6%	1.5%

The results of both the study indicates that the attachment of the base of the posterior papillary muscle of the left ventricle is more frequently to the middle third of the ventricular wall .

Regarding the number of the papillary muscles , the present study indicates , the anterior papillary muscle had

one belly in 71%,

two bellies in 18%,

three bellies in 9% ,

four bellies in 1% and

five bellies in 1%

The previous study done by S Victor and VM Nayak indicated, The antieror papillary muscle had

one belly in 67%,

two bellies in 27%,

three bellies in 4% ,

four bellies in 1% and

five bellies in 1%

	Present study	**Previous study**
one belly	71%	67%
two bellies	18%	27%
three bellies	9%	4%
four bellies	1%	1%
five bellies	1%	1%

the two results are more or less similar.

The present study indicates , the posterior papillary muscle had

one belly in 48%,

two bellies in 39%,

three bellies in 8% ,

four bellies in 4% and

five bellies in 1%

The previous study by S Victor and VM Nayak indicated , the posterior papillary muscle had

one belly in 50%,

two bellies in 36%,

three bellies in 11% ,

four bellies in 3% and

five bellies is not encountered at all.

	Present study	**Previous study**
one belly	48%	50%
two bellies	39%	36%
three bellies	8%	11%
four bellies	4%	3%
five bellies	1%	nil

On comparing the chordal attachment to each papillary muscle there were minimum of three chordae tendinae from each of the anterior papillary muscle, maximum of the 14 and mean of 8.

From the posterior papillary muscle, corresponding data were 2, 15 and 6.

From the anterior papillary muscle of the right ventricle it was 1, 6 and 4.

From the posterior papillary muscle of the right ventricle it was found be 1, 14, and 2.

From the septal papillary muscle the corresponding data was 1, 6 and 3.

The previous study of Victor and Nayak showed the following results.

Minimum of 4 chordae tendinae from each of the anterior papillary muscle maximum of the 22.

From the posterior papillary muscle, the corresponding data was 2 and 18.

Anterior papillary muscle of the left ventricle

	Present study	Previous study
Minimum number of chordae	2	4
Maximum number of chordae	14	22
Mean value	8	---

Posterior papillary muscle of the left ventricle

	Present study	Previous study
Minimum number of chordae	2	2
Maximum number of chordae	15	18
Mean value	6	---

Regarding the variations in the anatomy of papillary muscle of right ventricle , previous study was done by NegriG.R., L. J. A Di Dio and C.A.C. Baptista. They concluded that papillary muscle of right ventricle had single belly in 81%, two in 19%, posterior papillary muscle was single in 25.4%, double in 46.8%, three in 21.5% and four in 6.3%. Septal papillary muscle of right ventricle was one in 1.7%, two in 16.5% and three in 12.7% and four in 7.6% . In 21.5% of specimen there was no distinct septal papillary muscle at all and chordae tendinae were seen to be arising directly from the ventricular wall.

These results were compared with the present study.

Anterior papillary muscle of right ventricle

	Present study	**Previous study**
Single belly	68%	81
Double bellies	27%	19%
Three bellies	5%	--

Posterior papillary muscle of right ventricle

	Present study	Previous study
Single belly	32%	25.4%
Double bellies	53%	46.8%
Three bellies	15%	21.5
Four bellies	----	6.3

Septal papillary muscle of right ventricle

	Present study	Previous study
Single belly	41%	41.7%
Double bellies	7%	16.5%
Three bellies	3%	12.7%
Four bellies	----	7.6%
Absent	49%	21.5%

On comparing the chordal attachment to each of the papillary muscle of right ventricle, the present study showed, minimum of one chordae tendinae from each of the anterior papillary muscle , maximum of six and mean value of four.

From the posterior muscles , the corresponding data was 1, 14 and 2.

From the septal papillary muscle the corresponding data was 1, 6 and 3.

The previous study done by Negri G.R., L. J. A Di Dio and C.A.C. Baptista showed the following results.minimum of 1 chordae tendinae from each of the anterior papillary muscle, maximum of 11 and mean value of 4.74.

From the posterior muscles , corresponding data was 1, 8 and 2.67.

From the septal papillary muscle the corresponding data was 1, 5 and 1.7.

Anterior papillary muscle of the right ventricle

	Present study	Previous study
Minimum number of chordae	1	1
Maximum number of chordae	6	11
Mean value	4	4.74

Posterior papillary muscle of the right ventricle

	Present study	Previous study
Minimum number of chordae	1	1
Maximum number of chordae	14	8
Mean value	2	2.6

Septal papillary muscle of the right ventricle

	Present study	Previous study
Minimum number of chordae	1	1
Maximum number of chordae	6	5
Mean value	3	1.7

Except for the mean value of chordae arising from the septal papillary muscle of the right ventricle all other data are correlating well in both studies.

SUMMARY

The variations in the papillary muscular anatomy is studied in a detailed manner in 100 human hearts. The results are more or less coinciding with that of the other studies done by eminent scientists in the field.

The following findings have been observed ; The left ventricle had showed two papillary muscles in most of the specimen studied; they arise from the anterolateral wall and posteromedial wall and each of them sends chordae tendinae to both cusps of mitral valve.

The anterior papillary muscle is largest of the papillary muscle; it had single belly in seventy one percent (71%), and that was the predominant pattern observed , more than one belly was observed in the remaining twenty nine percent of specimens studied.

The anterior papillary muscle seen arising from upper third in sixteen percent (16%), from the middle third in seventy four percent (74%) and from the lower third in ten percent (10%).

The posterior papillary muscle was found to be having single belly in forty nine percent(49%), more than one belly in the remaining fifty one percent of the specimens studied , so in the case of posterior muscle the pattern of having more than one belly was the more frequent finding.

The posterior papillary muscle was seen arising from the upper third in thirteen percent (13%), from the middle third in eighty one percent (81%), and from the lower third in six percent (6%) of the specimen studied.

In the right ventricle there was larger anterior papillary muscle which was having single belly in sixty eight percent(68%) and more than one belly in the remaining thirty two percent of the specimens.

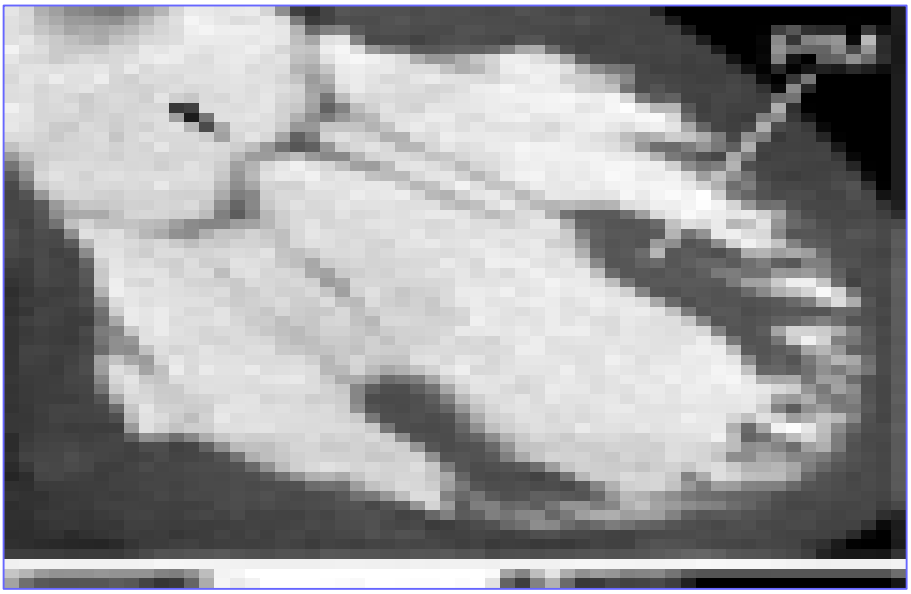
The posterior muscle was having predominant pattern of having two bellies which were smaller in dimension compared to the anterior papillary muscle , the percentage having two bellies was fifty three (53%).

The septal muscle was the most inconstant one and was absent in as many as forty nine(49%) percent of the specimens studied.

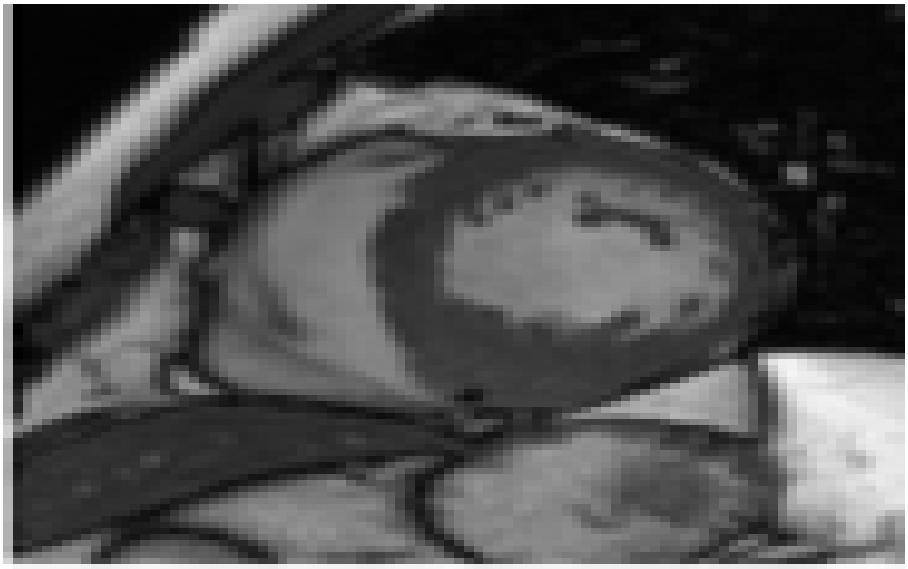
The attachment of the base of the anterior and posterior papillary muscles was in the middle third mostly ;in eighty three percent (83%) for anterior and eighty eight percent (88%) for posterior muscle, but in septal papillary muscle the upper third attachment predominate that was in fifty eight percent (58%).

The chordae tendinae arising from each of the papillary muscle seen varying to a great extent , it was found to be numerous from the anterior papillary muscle of the left ventricle which showed an average of eight and the least from the posterior muscle of the right ventricle which showed an average of two.

MRI picture of papillary muscle of the left ventricle showing single anterior and single posterior papillary muscle



Short axis view



Single anterior single posterior and three septal muscle in the right ventricle

Single anterior and single posterior papillary muscle in left ventricle

single anterior and two posterior papillary muscles in the left ventricle

Single anterior, two posterior and two septal muscles in the right ventricle

Single anterior and two posterior papillary muscles in the left ventricle

Single anterior and two posterior papillary muscles in the left ventricle

Single anterior and three posterior papillary muscle in the right ventricle

Two anterior papillary muscle bridged at the base with four septal papillary muscles in the right ventricle

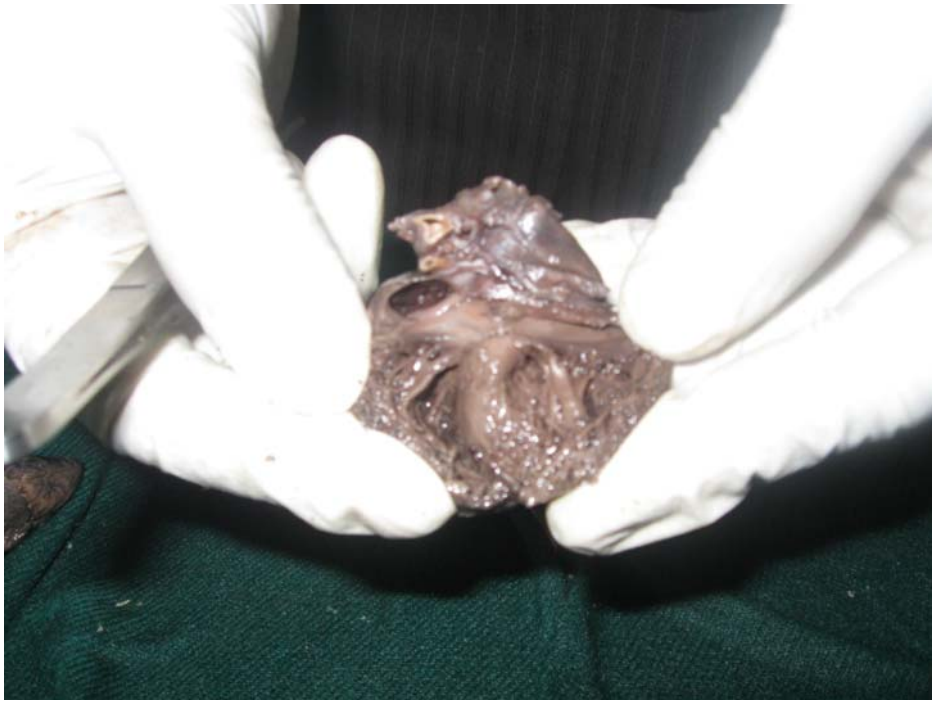
Single anterior and three posterior papillary muscles in the left ventricle

Single anterior three posterior papillary muscles in the right ventricle

Two anterior and two posterior papillary muscles in the left ventricle

Single anterior, single posterior and four septal papillarymuscles in the right ventricle.

Single anterior and single posterior papillary muscle in the left ventricle of neonatal heart



Single anterior and posterior papillary muscles in the left ventricle of the neonatal heart